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CONFIDENTIAL

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REPORT and PROPOSAL

CROSSBOW PROJECT

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REPORT OF WORK DONE TO DATE

1. **The Basic Problem**

Our assignment was to build several crossbows based on plans originally published in POPULAR SCIENCE, POPULAR MECHANICS and elsewhere. These designs were to be modified so that the weapons could be disassembled and carried in a suitcase, and further modified so that it would be possible to shoot a 215 lb. line (or, failing that, a lighter leader line) for a distance of 300 ft. It was further desired to modify the weapons so that they would be quiet.

It was suggested that an 80 lb. pull would be about the maximum permitted for the cocking lever. The suggested rifle bow maximum pull was 240 lbs.

2. **The First Model**

A rifle type crossbow was built, following POPULAR MECHANICS plans very closely, (modified only to permit the operator to take the stock apart). Attempts to shoot a line the required distance were unsuccessful, leading to many additional modifications in the original model. Some of these changes were:

(a) String — Made of aircraft control cable instead of linen thread.

(b) Arrows — Made of aluminum and steel, instead of wood, to give the extra weight needed to carry a line.

(c) Bow

A great many bows were tried, each more powerful than the last. At one point six 1/8" thick leaves were piled on top of each other to produce a composite spring 3/4" thick. It was found to be more efficient to replace this pile with a single 1/4" leaf laminated with a single 1/8" leaf. This combination pulled about as hard as the pile of six, and shot a little farther. Some difficulty was encountered in locating a 1/4" spring material which would deflect to the amount desired (in such a short length) without taking a permanent set. In fact, about four springs failed before a successful design and material were found. In the final model, silicon-manganese steel is used. It is being used to the limit of its endurance, too, and must be carefully tapered to avoid failure. It is also important to support the center of the bow on both sides to prevent severe bending at the high stress, notch points.

(d) Bow Stock — The stock was altered to permit disassembly.

(e) Trigger — As the bow weight increased, it became more and more difficult to pull the trigger. The POPULAR MECHANICS version had to be replaced by the "full-hand" model now on the bow.

(f) Trigger Shaft — Failed under the heavier bows and had to be replaced with a larger diameter pin.

(g) Release Nut — Cut the bowstring, and had to be rounded to avoid this. Also was the source of a good deal of noise, as it had a tendency to spin on its axis and hit the trigger repeatedly. Had to be carved up to avoid this.

(h) Cocking Lever — The original lever, built to POPULAR MECHANICS plans, failed twice in use. The bent wire bow-grip unbent, and had to be replaced with steel plates. The wooden bars used to push the bowstring shattered, and were replaced by metal. Finally, the design of the cocking lever caused the bowstring to be pushed down against the bow stock during the start of the cocking stroke. This damaged the string, and so a small roller was mounted on the end of this member. The final cocking lever works, but is not very convenient or easy to use.

(i) Bow "nocks" — The plastic nocks holding the bowstring failed, and were replaced by brass.

As a result of all the changes mentioned above, it can be seen that the final model differs from the original POPULAR MECHANICS version in all but a couple of minor parts.

3. Shooting a Line

A great many of the modifications in design listed above were made necessary by the fact that the POPULAR MECHANICS crossbow was only able to shoot a line about 30 yards. To achieve greater distance, it was necessary to increase the amount of energy delivered by the bow to the arrow, and this meant heavier bows. The heavier bow led to the other changes.

A great deal of experimentation was necessary on the choice of line used, and on the methods of handling this line. Commercially-available bow-fishing equipment was bought, but was next to worthless. Attempts were made to coil the line in a barrel, like the whalers used to do, but this was very time-consuming and uncertain with the small lines being used. (We needed small diameter lines to even approach the required 300 ft.) We finally settled on a salt-water spinning reel, filled with 20 lb. test monofilament, nylon line. This is easy to use and offers very little resistance to the line. A 300 lb. test braided Dacron line has been pulled through the branches of several large trees with the nylon line without breaking the nylon.

A satisfactory method of mounting the spinning reel on the crossbow was not discovered as the project expired before this could be done. The best position for the reel seems to be above and behind the rear end of the arrow, however. Attempts to mount the reel underneath the bow tangled the bowstring with the nylon line, breaking the latter.

4. <u>Arrows</u>

The arrow weight is important. If the weight is too light, "muzzle" velocity is high and air resistance seriously limits the flight. If the weight is too great, however, then muzzle velocity is low, and the maximum possible time of flight (and hence, distance) is decreased. There is, therefore, an optimum weight. As accurate calculations of this weight would require detailed knowledge of such unknowns as air resistance versus velocity for the arrow, the optimum was sought by building a number of arrows of differing weights and shooting them. The optimum seems to be about 130 grams. The peak is rather broad, however, so the weight is not critical.

Molded rubber vanes were used for "feathers" on the arrows. These are perfectly satisfactory when a line is attached to the rear of the arrow for additional stabilization. However, if it is desired to make long shots with a hunting arrow, with no line, then larger feathers would probably be necessary.

The line, incidentally, is best fastened to the rear of the arrow, just behind the feather, contrary to standard bow-fishing practise.

5. Stringing the Bow

POPULAR MECHANICS suggested that the bow be strung placing it on two blocks of wood to raise it off the floor and stepping on the center. This doesn't even begin to work with the 1/4" spring. It was necessary, therefore, to develop a convenient way of stringing the bow without overstressing it. The system finally evolved is to pass a heavy line over one end of the bow, then under the foot of a bumper jack and then fasten it to the other end of the bow. The top of the jack is then braced against the center of the bow. Operating the jack bends the bow enough to permit a new string to be mounted.

6. Noise

Some unsuccessful attempts were made to quiet the bow. The string was wrapped in cloth, the bow was wrapped in cloth, the bowstock was lined with cloth, felt bumpers were mounted on the bow to catch the bowstring. Nothing seemed to make much difference in the noise level without also making a big difference in the flight distance. The general philosophy behind our attempts was to take the noise out of the system after the string had finished pushing the arrow but before the string had snapped against the bow or started vibrating.

PROPOSAL FOR ADDITIONAL WORK

There are several obvious improvements which could be made in the bow as it now stands. There are other refinements which could be made if it is felt that the bow is really promising. Let's consider, first, the obvious ones, then the more complex steps:

Simple Improvements

1. Cocking Lever

The present cocking lever should be fastened to a large cement block and dropped into the Mindanao Trench. Or maybe the AEC could be talked into atomizing it. In any event, I don't wish to see it again. A far better solution would be a standard bumper jack, equipped with suitable clamps. This would make the job of cocking the bow easier, safer, and more convenient. The same jack could also be used for mounting new bowstrings.

2. Mounting the Spinning Reel

This will require some experimentation. A position above and behind the arrow is good for the line, but poor for the operator - unless the reel is mounted on the operator's shoulder, which is a definite possibility. In any event, there do not seem to be any really serious problems to be overcome. The reel works, and it can be mounted.

More Complicated Changes

3. Noise

If it is felt that the present bow is too noisy, it will be necessary to do quite a bit of experimentation. We would recommend that, as a first step, some high speed movies be taken of the gun in action. There is an outfit in Waterbury, Connecticut (Industrial Photo Service, Inc.) which does this kind of work. Sufficient movies could be made for about $250 to show just what is hitting what, which parts are vibrating, which scraping, etc. This slow-motion picture should give us the information we need to design noise reducers.

4. Power Increase

If silencers are added, there is an excellent chance that they will steal power from the present system. As we are barely able to shoot the 100 yards now, this will necessitate an increase in the power of the bow or, less likely, refinements to increase the efficiency. The bumper jack cocking system may make it possible merely to add addtional leaves to the present bow, or to replace the present 1/8" leaf with a second 1/4" leaf. What effect this will have on other parts, however, we do not know. Increasing bow power has always caused a multitude of changes before, and we would be brash to claim it would not again. Noise reduction schemes tried so far have reduced flight distances by as much as 50%. If it is necessary to double the bow power, it is certain that other changes would be necessary. (And would double power require double silencers?) It is hoped, of course, that more efficient silencers could be developed.

It might be possible to increase power without increasing noise, by lengthening the stroke of the bow without altering its maximum draw force. The amount of energy delivered to the arrow would be greater, but the amount lost in noise would be comparable to that in the present weapon. (The noise seems to come at the end of the stroke.) However, to increase the stroke of the bow, it will be necessary to lengthen it. Space limitations then force us to divide the bow into two sections at the middle. This changes several other major parts of the system - including the stock, which would have to be lengthened, and might have to be folded in two places instead of one. Again it looks like a fairly long program.

5. In General

The crossbow has one big advantage - the power to drive projectiles is always present, built right into the gun. There is no need for special cartridges or fuel sources. It has the disadvantage, though, of being bulky and a little awkward to handle. A really powerful bow would be quite heavy. It would be possible to retain the "stored energy" advantage, and yet obtain a more compact package, by replacing the steel bow with a length of 600 lb. aircraft shock cord. This material is light, flexible, and reliable. It can be stretched repeatedly 100% of its rest length without failure. It would seem that this approach could result in an improved weapon.

6. Possible "Next Steps"

Three different programs are possible as a next step.

(a) If the present weapon is satisfactory from a noise, power and weight standpoint, it would be necessary only to take the steps listed in paragraphs (1) and (2) above; namely, build an improved cocking lever and mount the reel on the stock. Such a program might take two weeks to one month for an engineer and a modelmaker.

(b) If noise is a problem, it will be necessary to take steps (3) and probably (4); in addition, of course, to steps (1) and (2). If the photographs are revealing, and if an efficient silencer can be found, this program could be quite short. We feel, however, that such a program would be more apt to involve and engineer and modelmaker for something like two or three months.

(c) If the shock cord is of interest, a weapon could be built for about the same price as was the present bowgun. Problems of line, reel, arrow weight, etc., will not have to be solved again but, of course, the main gun elements will all have to be redesigned.

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